

Management of Global Nuclear Materials for International Security

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Management of Global Nuclear Materials For International Security

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Abstract – Nuclear materials were first used to end the World War II. They were produced and maintained during the cold war for global security reasons. In the succeeding 50 years since the Atoms for Peace Initiative, nuclear materials were produced and used in global civilian reactors and fuel cycles intended for peaceful purposes. The Nonproliferation Treaty (NPT) of 1970 established a framework for appropriate applications of both defense and civilian nuclear activities by nuclear weapons states and non-nuclear weapons states. As global inventories of nuclear materials continue to grow, in a diverse and dynamically changing manner, it is time to evaluate current and future trends and needed actions: what are the current circumstances, what has been done to date, what has worked and what hasn't? The aim is to identify mutually reinforcing programmatic directions, leading to global partnerships that measurably enhance international security.

Essential elements are material protection, control and accountability (MPC&A) of separated nuclear materials, interim storage, and geologic repositories for all nuclear materials destined for final disposal. Cooperation among key partners, such as the MPC&A program between the U.S. and Russia for nuclear materials from dismantled weapons, is necessary for interim storage and final disposal of nuclear materials. Such cooperative partnerships can lead to a new nuclear regime where a complete fuel cycle service with fuel leasing and spent fuel take-back can be offered to reactor users. The service can effectively minimize or even eliminate the incentive or rationale for the user-countries to develop their indigenous enrichment and reprocessing technologies. International cooperation, supported by governments of key countries can be best to facilitate the forum for formation of such cooperative partnerships.

1. INTRODUCTION

Nuclear materials were first used to end the World War II. Since then, special nuclear materials (plutonium and highly enriched uranium (HEU)), and know-how and technologies of producing them were sought after by countries for reasons of national security. These materials were produced rapidly in quality and quantity during the Cold War arms race, and were maintained by defense programs between the U.S. and the former Soviet Union, and in a few other nuclear-weapon countries.

Because of its high-energy density, nuclear material is also an attractive source of energy. The controlled release of this energy was first accomplished in the CP-1 reactor in 1942. Since then, countries seek the reactor and fuel cycle technologies for reasons of energy security. 50 years ago, such technologies were promised by the “Atoms for Peace” program of the U.S.^[1] to countries which pledged not to develop nuclear weapons. Nuclear materials were produced and used in global civilian reactors and fuel cycles intended for peaceful purposes.

The growth and spread of nuclear technologies and materials through “Atoms for Peace” and other means raised concerns for global nuclear proliferation. The Nonproliferation Treaty (NPT), established in 1970 was intended to codify and put in place a framework for appropriate applications of both defense and civilian nuclear activities by nuclear weapons states and non-nuclear weapons states. The NPT experienced positive though imperfect results in terms of its effectiveness in preventing nuclear proliferation. It was indefinitely extended since 1995 and remains the only global regime in regulating the peaceful use of nuclear materials.

The end of the Cold War introduced a large inventory of special nuclear materials from dismantled weapons in the U.S. and Russia. The subsequent break-up of the former Soviet Union raised concern for physical protection and control of the nuclear materials still residing in the economically-stricken Russia and the former Soviet Republics. The 9/11/2001 terrorist attack on the U.S. and the war on terrorism highlighted and reinforced an urgent dimension for protection of

nuclear materials - to prevent their acquisition and use by rogue countries and terrorist groups.

As global inventories of nuclear materials continue to grow, in a diverse and dynamically changing manner, it is time to evaluate the current situation on nuclear material management and to identify mutually reinforcing programmatic directions, leading to global partnerships that can measurably enhance international security.

2. CURRENT SITUATION

Today, over 400 nuclear power plants, in about 40 countries, produce 16% of the world's electrical energy. The result to date is the accumulation of approximately 230,000MT of spent fuel, stored mainly at nuclear reactor sites. The fission process transforms the essentially non-radioactive, non-weapons-usable fresh fuel into highly radioactive spent fuel containing significant quantities of weapons-usable plutonium.

Reprocessing a portion of this spent fuel in a few countries is resulting in an increase of separated plutonium that will reach an estimated 250MT (in excess of 500,000 lbs) by 2010. Several countries recycle their separated plutonium as MOX in nuclear reactors. But the majority of the separated plutonium stock will be indefinitely stored, raising non-proliferation and physical protection concerns. Also, there is well in excess of 1000MT of additional plutonium in the remaining spent fuel. While the intense radioactivity of spent fuel provides a degree of self-protection from terrorist actions, the plutonium remains a security issue when it exists in countries of proliferation concern.

Weapons-dismantlement agreements between the U.S. and Russia resulted in a total of 100MT of weapons plutonium and 674MT of HEU declared excess of their respective defense programs. Much of these excess weapons materials and the HEU from the Reduced Enrichment of Research and Test Reactors (RERTR) program will be dispositioned in civilian reactors and fuel cycles, adding additional burden for safe and secure management to existing nuclear materials.

The future of nuclear power, however, remains uncertain and is likely to experience some important shifts. Although it is anticipated that most of the existing plants will continue to operate for some time, opinions vary widely over whether and where new nuclear power plants may be built in the developed countries.

What appears likely is that over the coming decades developing countries, particularly in Asia, will experience the greatest growth in electricity demand as populous countries strive to improve their standards of living. Resource, environmental, and economic pressures will make new nuclear power an attractive option for many. Thus we are likely to see a significant change in the growth and spread of nuclear power and the consequent buildup of spent nuclear fuel in the coming decades. Along with it may come the desire for some of these countries to have the enrichment and reprocessing capabilities necessary if they are to maximize their self-reliance in electricity production.

As the continuing dilemmas arising from the proposed Russian sale of nuclear reactors to Iran and recent events in North Korea highlight, the spread of civilian nuclear materials, know-how and facilities brings with it new proliferation risks. Understanding and shaping the directions of civilian nuclear power growth and the management of the global inventories of nuclear materials will have a profound effect on the unfolding changes in the international security landscape.

3. ESSENTIAL ELEMENTS

3.1 Separated Nuclear Materials

There is no question that nuclear materials need active management, and will for generations. First and foremost is the management of the existing stock of separated nuclear materials, especially the separated plutonium (civil and weapons) and HEU. Material protection, control and accountability (MPC&A), secure storage, and utilization programs are essential elements for managing separated nuclear materials.

To secure the nuclear materials after the Cold War, the U.S. implemented a MPC&A program and assisted Russia in managing its nuclear materials, including those from weapons dismantlement. The U.S. purchased 500 MT of HEU from Russia, and blended them down to LEU for use in LWRs. (The U.S. also has ~174 MT of excess HEU from dismantled weapons.) A facility, financed by the U.S. and others, is built in Mayak to store the Russian declared excess weapons plutonium. In addition, the U.S. and Russia signed a bilateral agreement to disposition 34 MT of weapons plutonium from each of their excess stocks. ^[2]

The separated plutonium can be used as fuel in nuclear reactors to produce useful energy. Tables 1 and 2 give the current global MOX fuel fabrication capacities and LWRs that use MOX fuel, respectively ^[3].

Table 1. Current MOX Fuel Fabrication Capacities

Country	Site	Plant	Capacity, Mg/y, (predicted)
Belgium	Dessel	P0	40 (40)
France	Cadarache Marcoule	CFCa MELOX	40 (0) 100 (200)
India	Tarapur	AFFF	10 (10)
Japan	Tokia Rokkasho	PFPF MOX FFF	15 (5) 0 (100)
Russia	Chelyabinsk	Mayak, Complex 300	0 (1) 0 (10)
United Kingdom	Sellafield	MDF SMP	8 (8) 120

Table 2. LWRs that use MOX fuel.

Country	No. of LWRs using MOX fuel	Forecast of LWRs Licensed to use MOX	Max. Burnup (GWd/t) of MOX fuel	Max. MOX Ratio (%) in core
Belgium	2	2	45	25
France	19	20	45	30
Germany	10	12	48	50
Japan	0	16-13	45	33
Switzerland	3	4	50	40
Russia	0	4	-	-
US	0	6	-	-

The plutonium content in MOX fuel for LWR is about 5%. The annual global MOX fuel fabrication capacity of about 300 MT amounts to a utilization of merely ~17 MT of separated plutonium. To accelerate the utilization of civil plutonium and accommodate the disposition of weapons plutonium, the current MOX fuel fabrication capacity needs to be expanded. The U.S. and Russia have plans to build their own MOX fabrication plants.

The separated plutonium can also be used in fast reactors (FRs). The advantage of fuel for FR over that of LWRs is higher tolerance of impurities. Despite of the shutdown of France's Super Phoenix and the temporary stand-down of Japan's Monju, several research FR projects are still under way. These include

the French Phoenix, the Japanese Joyo, and the Russian Federation's BOR-60, and a power FR, BN-600.

The separated plutonium can be immobilized with high-level radioactive wastes ^[4], and be directly disposed of in a geologic repository. It can also be fabricated as "dirty MOX" in an assembly which does not meet the specifications for MOX fuel. The intent would be to mix the dirty MOX assemblies with regular spent fuel assemblies for final geologic disposal.

These options aim to put separated plutonium back into an un-separated (or hard-to-separate) form and provide self-protecting radiation to complicate its further separation. The self-protecting radiation will add a measure for physical protection; however, its effectiveness is time dependent and governed by radioactive decay.

3.2 Spent Fuel

The spent fuel has self-protecting radiation for the unfissioned and newly generated nuclear materials. Spent fuel can be reprocessed to recover the nuclear materials and recycled them to reactor for energy generation. The reprocessed wastes will need to be stored and ultimately disposed of. If spent fuel is not reprocessed but considered as wastes, the storage, transportation, and ultimate disposal are the essential elements for managing spent fuel.

To date the majority of spent fuels continue to be stored at the reactor sites where they are created. The situation raises several concerns on security and nonproliferation: The spent fuel could

- Become terrorist targets if physical protection is inadequate,
- Be diverted for clandestine weapons program in countries of proliferation concerns,
- Be reasons for a country to pursue its own fuel cycle (reprocessing, fuel fabrication, and enrichment) technologies,
- Be a burden to a country lacking its own resources (financial and land) to deal with the ultimate disposal.

To address the nonproliferation and wastes issues of managing nuclear materials in the nuclear fuel cycles, a global network comprising of current nuclear fuel cycle facilities was previously proposed ^[5]. The proposal envisioned a full fuel cycle service to be provided competitively by a network of fuel cycle facilities currently operating by companies (such as Areva, BNFL, Westinghouse, GE, etc.) to reactor users

(utilities and/or countries). With reliable fresh fuel supply and the take-back of spent fuel, the reactor users can forego building their own fuel cycle facilities, including enrichment, reprocessing and repository. In fact a key objective is to minimize and even eliminate the incentive or rationale for non-nuclear weapons countries to develop enrichment or reprocessing capabilities to service their civilian nuclear power programs. For those countries that would choose not to accept the offer (for example, Iran) they must accept and pay for the most stringent IAEA safeguards (at a minimum, adherence to the Additional Protocol).

It is recognized that not many countries can by themselves provide a full fuel cycle service (for example, a waste repository is a challenge). The network can hence provide an opportunity for the fuel-cycle countries to form partnership so that a complete fuel cycle service can be offered. Such partnership can best be worked out by contractual arrangements (like those in the business world). However, formulation of the network would require the understanding, stewardship and support of major governments (with U.S. leadership as the most important element). This governmental cooperation is most needed in programs of interim storage and final disposal in repository.

Many national storage and repository programs have been considered. Most were stymied, abandoned, reconfigured, and mired in political and institutional stalemates that exceed even the daunting technical challenges. A small number of noteworthy national efforts continue to make progress.

Siting facilities and public acceptance remain formidable obstacles. A number of regional concepts^[6,7] for the management and disposal of these materials have been put forward, but there has been little agreed international effort. There are a number of difficult barriers. Timing is key as many countries worry that premature movement toward regional or international solutions may undermine existing national programs seen as necessary precursors. Economics, political, and security concerns have complicated each attempt.

4. ISSUES WITH REGIONAL STORAGE

As technologies for spent fuel/waste storage facilities are well developed and commercially available, issues that remain of interest are primarily institutional. Some of these are:

4.1 Interim Storage Duration

Provide a full core reserve capability for the Interim spent fuel storage is defined as the period when spent

fuel is discharged from the reactor till it is either emplaced in a geologic repository, or sent to a reprocessing facility for chemical processing. Interim storage is needed to satisfy one or all of the following:

- Continued operation of the reactor,
- Allow for the decontamination of the reactor,
- Allow for the decommissioning of the nuclear plant site.

The duration of interim storage depends on the nuclear back-end policy of the country/utility, i.e., whether direct disposal or reprocessing and recycling of spent fuel. It also depends on the different phases of its reactor operation. Interim storage for spent fuel should be adequately provided when the plant is in operation. The challenge arises when the plant is decontaminated and decommissioned (D&D). If a country is incapable of providing AFR spent fuel storage due to limited resource (finance or land), it would have to seek other cooperative frameworks such as regional storage before final solution on spent fuel management is obtained.

4.2 Financial Aspect of Interim Storage

The cost of interim spent fuel storage depends on the provision by the country/utility for the back-end nuclear fuel cycle. In the U.S.^[8], the nuclear utilities pay 1 mill/kWh to the USDOE for management costs of their spent fuel. Other countries may have to allow for a higher fee because of their smaller sizes of generating capacities.

There are countries storing others' spent fuel for a fee. For example, Russia^[9] accepts the Ukrainian's VVER-1000 spent fuel for storage and charges a fee of about US\$350/kgHM (1999). Russia also revised its Environmental Law to accept spent fuel from other countries for a fee of about US\$2000/kgHM^[10] (the fee may include the final disposal of spent fuel).

The proper charge for spent fuel storage remains a challenge to regional/international cooperative frameworks.

4.2.1 Impacts of Regional Arrangement to a National Program

There is a concern that regional cooperative arrangement for spent fuel storage may upset a national storage program. The concern arises from a perception that with regional approach the domestic solutions are not needed any more. The public of the host country also has concern of "foreign dumping" of wastes. To allay such concerns, regional cooperative framework

must consider mutual needs and benefits of all parties involved.

4.4 Transportation

Spent fuel and wastes transported to regional site across national boundaries and/or across international waters must address complex issues involving international transportation of hazardous and radioactive materials. Furthermore, transport of spent fuel must be safe and secure, and comply with all international treaty requirements.

4.5 Other Concerns

- Liability aspect: who should pay for damages due to catastrophic accidents?
- Regulatory framework: what should be adopted? National requirements or international standards?
- Legal ownership: Does the host country own? Or other contractual party countries?

5. OPPORTUNITIES IN INTERNATIONAL COOPERATION

5.1 International Consensus on Spent Fuel and Radioactive Waste Storage

The Joint Conventions^[11] on Safety of Spent Fuel and Radioactive Waste Management of IAEA establish the international consensus on the safety aspect of spent fuel/waste storage.

IAEA also provides safeguards of nuclear materials and facilities through international agreements⁶. There are also regional safeguards arrangements by groups of countries geographically located, e.g., Euratom, and ABACC. To date, the international safeguards system continues to work well in the great majority of countries where the IAEA reporting and inspection regime operates to provide confidence that civilian nuclear materials and facilities are not being diverted to nuclear-weapons programs.

5.2 Exchange of Information, Knowledge and Experience

International cooperative forum can provide opportunities for exchange of information, knowledge and experience. Meetings and conferences can be convened, on specific topics or studies with the aim of sharing knowledge and experience among interested parties. Experimental facilities, specialized computer

programs and accumulated data and results could be mutually used and exchanged among parties contributing to the cooperative effort.

5.3 Roles for International Cooperation on Regional Spent Fuel Storage

- International Organizations (IAEA, others): To provide international consensus and support and to facilitate the exchange of information, knowledge and experience,
- Regional Parties: To involve all parties (including the international organizations) in decision-making process and to make regional spent fuel storage a success,
- Host Country: To ensure government and public support
- Party Country: To provide support to host country and meet contractual/regional agreements

6. CONCLUSION

There is no question that nuclear materials need active management, and will for generations. For separated nuclear materials, the material protection, control and accountability (MPC&A), secure storage, and utilization programs are essential elements for management.

Over the coming decades, the growth and spread of civilian nuclear applications, particularly for the production of electricity, are likely to occur in developing nations. Over time the resultant spent fuel storing at sites in many countries including some with lesser nonproliferation credentials and some with limited resources (finance and land), may become new security, environmental and political concerns.

Regardless of a country's back-end fuel cycle policy, i.e., once-through, reprocessing and recycling, or wait-and-see, storage of spent fuel and a geologic repository for all nuclear materials destined for final disposal are essential elements for the country's civilian nuclear program.

Storage and repository are key elements for a global network of fuel cycle facilities. With these elements, the cooperative partners within the global network can offer a complete fuel cycle service including fuel leasing and spent fuel take-back to reactor users. The service, if competitively and adequately provided, can effectively minimize or even eliminate the incentive or rationale for the user-countries to develop their indigenous enrichment and reprocessing technologies, a major longer-term security objective.

There are many challenges on storage and repository, especially in regional and/or international settings: such as, who provide such storage and /or repository? For how long? At what costs? Who are legal owners? Who is liable for damages due to catastrophic accidents? In transportation? And how about public acceptance?

Despite the challenges, in international cooperation, supported by governments of key countries can:

- • Facilitate forum for formation of cooperative partnerships within the global network,
- • Provide consensus in safe and secure storage of spent fuel and radioactive wastes,
- • Enhance confidence-building measures and help allay local public concerns, and
- • Facilitate the exchange of information, knowledge and experience.

The secure management of nuclear materials in a cooperative global network can potentially further the growth and spread of nuclear power in a manner that, over time, reduces the proliferation, waste and environmental concerns below where they are today.

References

1. “Atoms for Peace” speech by President Eisenhower to the U.N. Assembly, 12/8/1953.
2. Agreement between the US and the Russian Federation concerning the management and

disposition of ex-defense plutonium, signed on 1 September 2000.

3. “Status and trends in spent fuel reprocessing,” IAEA TECDOC-1103, August 1999.
4. P. G. Harrington, et. al., “Considerations for disposal of immobilized plutonium waste form in a repository,” paper presented at the IAEA TCM on “Utilization and Disposition of Plutonium” in Brussels, Belgium, and October 2000.
5. J. S. Choi and T. Isaacs, “Toward a New Nuclear Regime,” paper presented at the ICAPP, Cordoba, Spain, in May 2003.
6. International Interim Spent fuel Storage (IIS), by A. Suzuki, University of Tokyo, Japan.
7. W. Hafari, et.al., “International Monitored Retrievable Spent fuel Storage,” presented at the Planetary Emergency meeting at Erice, Italy, August 1996.
8. U.S. Nuclear Waste Policy Act, 1982.
9. Nucleonics Week article, Oct. 1999.
10. Proposal by the Non-Proliferation Trust.
11. IAEA Conventions entered into force in July 2001.

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